PCT/AU2004/000915

Australian Government

REC'D 28 JUL 2004

WIPO PCT

Patent Office
Canberra

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003905861 for a patent by COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION as filed on 24 October 2003.

COMMONWEALTH OF AUSTRALIA
AUSTRALIA
PATENT OFFICE

WITNESS my hand this
Fifteenth day of July 2004

J. Billingsley

JULIE BILLINGSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Applicant:

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION

Invention Title:

METHOD OF ENCODING A LATENT IMAGE

The invention is described in the following statement:

METHOD OF ENCODING A LATENT IMAGE

Field of the Invention

The present invention relates to a method of encoding a latent image. Embodiments of the invention have application in the provision of security devices which can be used to verify the legitimacy of a document or instrument, for example, a polymer banknote.

Background to the Invention

In order to prevent unauthorised duplication or alteration of documents such as banknotes, security devices are often incorporated within banknotes as a deterrent to copyists. The security devices are either designed to deter copying or to make copying apparent once copying occurs. Despite the wide variety of techniques which are available, there is always a need for further techniques which can be applied to provide a security device.

Summary of the Invention

The invention provides a method of encoding a latent image, the method involving:

a) providing a primary pattern having a plurality of primary image elements, the primary pattern being capable of decoding the latent image once the latent image has been encoded;

b) providing a latent image to be encoded, the latent image having a plurality of latent image elements, each latent image element having a visual characteristic which takes one of a predetermined set of values;

c) relating the latent image elements to the primary image elements; and

d) forming a secondary pattern in which the

primary image elements are displaced in accordance with the value of the visual characteristic of the latent image elements with which they are related.

The image elements are typically pixels (i.e. the smallest available picture element), however, the image elements may be larger than pixels in some embodiments - e.g. each image element might consist of 4 pixels.

The visual characteristic typically relates to the density of the image elements. That is, where the latent image is a gray-scale image, the visual characteristic may be a gray-scale value and where the latent image is a colour image, the visual characteristic may be a saturation value of the hue of the image element.

The number of values in the predetermined set of values of the visual characteristic is typically dependent on the configuration of the primary pattern. The primary pattern typically consists of rectangular groups of image elements arranged in such a way that if the primary pattern were superimposed upon itself at a certain displacement it would eclipse it's own image. The number of image elements in each group of image elements limits the number of values in the predetermined set of values.

For example, a typical primary pattern for use in encoding a gray-scale latent image is a rectangular array consisting of a plurality of pure opaque vertical lines, each line being N pixels wide and separated by pure transparent lines of the same size. Such a primary pattern can be used to encode a latent image having up to N + 1 different gray-scale values.

In some embodiments, relating the latent image elements to the primary image elements involves associating the latent image elements with primary image

elements, whereafter the primary image elements are displaced in dependence on the value of the visual characteristic of the latent image elements with which they are associated.

In other embodiments, relating the latent image elements to the primary image elements involves separating the latent image into a plurality of masks corresponding to each value of the visual characteristic, forming a plurality of displaced partial primary patterns, and using the masks to cut out portions from the plurality of displaced partial primary patterns. When the displaced partial patterns are combined into the secondary image, the primary image elements are displaced in accordance with the value of the visual characteristic of the latent image elements with which they are related.

Typically, the primary pattern and the latent image will be rectangular and hence their image elements will be arranged in a rectangular array. Accordingly, displacing image elements will usually involve displacing image elements along one or both axes of the rectangular array. However, the image elements may be arranged in other shapes.

In one embodiment where image elements are displaced along the horizontal axis of the array and there are S different values of the visual characteristic, image elements having the first value of the visual characteristic are displaced horizontally by 1 image element, and each subsequent visual characteristic is displaced by a further image element so that the S^{th} shade is displaced by S image elements.

However, any number of different displacement schemes may be used. For example, the image elements may be displaced in accordance with the formula: displacement

(D) = (N-1)* [$(S-S_{min})/(S_N- S_{min})$]; where S is the value of the visual characteristic being displaced, S_{min} is the sparsest density value of the visual characteristic and S_N is the densest value of the visual characteristic.

Typically, the method will involve forming the latent image from an original image by image processing an original image to reduce the number of values of the visual characteristic in the original image to the number of values required in the latent image.

The invention also extends to a security device or a novelty item produced by the foregoing method as well as to documents or instruments incorporating a security device or produced by the method.

Further features of the invention will become apparent from the following description of preferred embodiments of the invention.

Brief Description of the Drawings

The preferred embodiments will be described with reference to the accompanying drawing in which:

Figure 1 is an original image of the example of the second preferred embodiment;

Figure 2 is a latent image of this example;

Figures 3a, 3b, and 3c are masks which are used in the example;

Figure 4 shows the different displacements used for different shades;

Figure 5 illustrates displaced primary patterns corresponding to Figure 4;

Figures 6 through 13 illustrate how the masked partial primary patterns may be combined to form the latent image; and

Figures 14 and 15 illustrate how the latent image may be retrieved using a decoding screen which consists of the primary pattern.

Description of the Preferred Embodiments

In each of the preferred embodiments the method is used to produce a secondary pattern in which a latent image is encoded. The secondary pattern in each case is produced by modification of a primary pattern in accordance with a relationship which is established between the primary pattern and the latent image which is to be encoded. The secondary pattern which is formed is a phase-shifted version of the primary pattern. The latent image can subsequently be viewed by overlaying the primary pattern with the secondary pattern.

Gray-scale embodiments

In the first and second preferred embodiments, the method is used to encode gray-scale images. In these embodiments, the set of values of the visual characteristic which is used as the basis of determining which displacement are to be applied to the primary pattern is a set of different shades of gray.

In the first and second preferred embodiments the image elements are pixels. Herein, the term "pixel" is used to refer to the smallest picture element that can be produced by the selected reproduction process - e.g. display screen, printer etc.

In these embodiments the primary pattern consists of rectangular groups of pixels arranged in such a way that if the primary pattern is superimposed on itself with a certain displacement it eclipses it's own image (to the extent that the primary pattern and the superimposed

primary pattern overlap). Each pixel in a group is either pure opaque (black) or pure transparent (white). The opaque and transparent groups alternate along at least one co-ordinate with at least approximate regularity. These groups will be referred to as "super pixels". Typically, the primary pattern will be a rectangular array of pixels. However, the primary pattern may have a desired shape - e.g. the primary pattern may be star-shaped.

A typical primary pattern for use in encoding a gray-scale latent image consists of a plurality of pure opaque vertical lines, each line being N pixels wide and separated by pure transparent lines of the same size. Such a primary pattern can be used to encode a latent image having up to N + 1 different gray-scale values.

In each of these embodiments, the latent image is formed from an original image. In gray-scale embodiments, the original image is typically a picture consisting of an array of pixels of differing shades of gray. However, the original image may be a colour image which is subjected to image processing to form a gray-scale image before subsequently being turned into a latent image. The original image is observed, in a simplified form, as the latent image when the primary pattern and the secondary pattern are overlaid.

In the gray-scale embodiments the latent image is a picture consisting of rectangular blocks of pixels. Each block consists of pixels with the same shade of gray. The number of shades of gray which can be used in different blocks are those required to display the latent image. The shades used in the latent image are a reduced set of the shades in the original image. The shades can be chosen in a number of different ways and might range from pure white to pure black. The blocks of pixels in the latent image do not have to be the same size as the super pixels, however,

in many embodiments they will be the same size.

The maximum number of shades (N_S) which can be used in the latent image d is controlled by the resolution of the reproduction technique and the preferred size of groups of pixels in the primary pattern. The number of encoded shades cannot exceed: N_S = (1 + the number of pixels in a super pixel of the Primary Pattern)

In the first preferred embodiment, the primary pattern is chosen to be a rectangular array (or matrix) of pixels. After a suitable primary pattern is chosen, the primary pattern is mathematically converted to a secondary pattern as follows:

1. The total number of possible shades (N_S) is determined from the composition of the primary pattern (i.e. the maximum dumber of shades which the chosen primary pattern is capable of encoding). Using standard image processing techniques known to persons skilled in the art, an original image is processed and digitised into an image containing N_S different shades of gray. This image is the latent image.

2. Each pixel in the latent image is assigned a unique address (p,q) according to its position in the [p x q] matrix of pixels. (If the latent image or the primary pattern is not a rectangular array then the position of pixels can be defined relative to an arbitrary origin, preferably one which gives positive values for both co-ordinates p and q).

3. Each shade of gray in the latent image is designated S_m, where S_1 is the palest shade of gray and S_{NS} is the darkest shade of gray (m = an integer between 1 and N_S).

4. Each pixel in the latent image is designated as belonging to one of S_1-S_{NS}.

5. Each pixel in the primary pattern is assigned a similarly unique address (p,q) according to its position in the [p x q] matrix.

6. The S_1-S_{NS} designation of each (p,q) pixel in the latent image is now assigned to the corresponding (p,q) pixel in the primary pattern to thereby relate pixels in the latent image to pixels in the primary pattern.

7. A mathematical operation is performed on each individual pixel in the primary pattern to move it along one of the image axes according to the shade of gray (S_m) assigned to it. This movement may be either right or left, or up or down, or combinations of movements along both of the axes simultaneously. A variety of displacements can be employed. In a common embodiment, each pixel is displaced as follows:

by 1 pixel for S_1

.....

by N_S pixels for S_{NS}

or, in general,

by m pixels for S_m

Alternatively, a formula such as the following can be used:

$$D = (N_S-1) \times [(S-S_{min})/(S_{max}-S_{min})]$$

where D = the displacement (i.e. the number of pixels to be moved)

Direct assignment of equally spaced D values to particular shades via a table is also valid method.

The pairing of darkest shade with highest shift can also be reversed i.e. lightest shade with highest shift will provide a similar result.

The formulae shown above provide a broad contrast range and hence make the latent image relatively easy to see when the primary pattern overlays the secondary pattern. Other formulae will be appropriate in other applications.

The resulting image is known as the secondary pattern. In the secondary pattern, pixels of the primary pattern have been displaced in accordance with the shade of gray of the pixel of the latent image with which they are related.

In the second preferred embodiment, once an appropriate primary pattern has been chosen, the primary pattern is manually converted (e.g. by a person manually operating a computer running appropriate software) to the secondary pattern as follows:

1. The total number of possible shades (N_S) is determined from the composition of the primary pattern.

2. Using standard image processing techniques known to persons skilled in the art, an original image is processed and digitised into an image containing N_S different shades of gray. This image is the latent image.

3. The latent image is then separated into N_S masks where each mask contains only the pixels belonging to one shade of gray (i.e. belonging to S_1-S_{NS}). This is achieved using standard methods in commercially available imaging

programs. After the masks have been formed each mask contains a unique set of pixels from the latent image and every pixel of the latent image can be found in only one of the masks. If all of the masks are combined correctly, the original picture can be restored.

4. A displaced partial primary pattern is created for each mask, with the displacement of each partial primary pattern corresponding to the shade of the pixels of the latent image to which the mask relates. These displaced partial primary patterns are designated $S*_1$-$S*_{NS}$. This displacement may be either right or left, or up or down, or combinations of movements along both of the axes simultaneously. The displacement is defined by a mathematical operation (algorithm) performed on each individual pixel S_1-S_{NS}. The displacement is different for each S_1-S_{NS}. A variety of displacements can be employed. In a common embodiment, each pixel is displaced as follows:

by 1 pixel for $S*_1$

.....

by N_S pixels for $S*_{NS}$

or, in general,

by m pixels for $S*_m$

Alternatively, formulas such as the following can be used:

$$D = (N_S-1) \times [(S-S*_{min})/(S*_{NS}-S*_{min})]$$

where D = the displacement (i.e. the number of pixels to be moved)

Direct assignment of equally spaced D values to

particular shades via a table is also valid method.

The pairing of darkest shade with highest shift can also be reversed - i.e. lightest shade with highest shift will provide a similar result.

The formulae shown above provide a broad contrast range. Other formulae will be appropriate in other applications.

5. The masks are used to cut-out sections of the corresponding displaced partial primary patterns, thereby relating the pixels of the latent image to the partial primary patterns. The resulting N_s masked partial primary patterns images are each portions of the displaced primary pattern.

6. The masked partial primary patterns are now recombined into the secondary pattern. The secondary pattern is thus, a displaced version of the primary pattern, where the displacement of individual pixels in the primary pattern is based on a relationship established between pixels in the latent image and pixels in the primary pattern.

Colour Embodiments

The methods of the third and fourth preferred embodiments are suitable for producing colour effects in encoded colour images. In the third and fourth embodiments, saturation level is the visual characteristic which is used as the basis for encoding the image. As in the first and second embodiments the image elements are pixels.

The primary pattern of the third and fourth embodiments is best explained with reference to the black

and white (B&W) primary pattern of the first and second embodiments. A colour primary pattern can be derived from a B&W primary pattern by substituting pixels of the chosen primary hues for the black groups of pixels in a B&W primary pattern in a regular fashion so that the primary pattern has a regular pattern of primary hues. These regular patterns may involve changing the hue of each succeeding pixel or multiple of pixels in a regular and repeating fashion. The saturation levels of these primary hues are determined as the maximum saturation levels found in the latent image. The transparent (white) areas may be filled with black or left white dependant on the requirements of the colour separation technique.

In these embodiments, primary hues are colours that can be separated from a colour original image by various means known to those familiar with the art. A primary hue in combination with other primary hues at particular saturations (intensities) provides the perception of a greater range of colours as may be required for the depiction of the subject image. Examples of primary hues are red, green and blue in the RGB colour scheme. Another colour scheme which may be used to provide the primary hues is CYMK.

In these embodiments, saturation is the level of intensity of a particular primary hue within individual pixels of the original image. Colourless is the lowest saturation available; the highest corresponds to the maximum intensity at which the primary hue can be reproduced. saturation can be expressed as a fraction (i.e. colourless = 0 and maximum hue =1) or a percentage (i.e. colourless = 0% and maximum hue =100%) or by any other standard values used by practitioners of the art.

As in the first and second embodiments, the latent image will typically be provided by forming it from

an original image. Typically, the original image will be a picture consisting of an array of pixels of primary hues with differing saturations of each primary hue. The original image is observed, in a simplified form, as the latent image when the primary pattern and the secondary pattern are overlaid. The latent image is a digitised and pixilated version of the original image.

The maximum number of saturation levels (N_S) of a particular primary hue which can be visible in the Latent Image is controlled by the resolution of the reproduction technique and the preferred size of groups of pixels in the primary pattern. The number of encoded saturation levels cannot exceed: N_S = (1 + the number of pixels in a super pixel of the primary pattern)

The methods of the third and fourth embodiments are also controlled by the number of primary hues (N_H) used in the colour separation technique.

In the third embodiment, once a suitable primary pattern has been chosen, the following steps are undertaken in the mathematical conversion of the Primary Pattern to the Secondary Pattern:

1. The total number of possible saturation levels (N_S) is determined from the composition of the primary pattern.

2. Using standard image processing algorithms known to persons skilled in the art, an original image is processed and digitised to the latent image, which is made to contain a maximum of N_S saturation levels in each one of the hues.

3. Each pixel in the latent image is analysed sequentially to determine the saturation of the primary

hue in the pixel.

4. Each pixel in the latent image is allocated a unique address [(p,q)nh] according to its position in the [p x q] matrix and its hue, nh (nh = 1 for hue number 1, nh = 2 for hue number 2, ... nh = N_H for hue number N_H). Again, as in the first preferred embodiment the co-ordinates may be defined relative to a reference point rather than as positions in a matrix, especially where the latent image is not a rectangular array of pixels.

5. Each saturation level in the latent image is designated S_m, where S_1 is the lowest saturation and S_{NS} is the most intense saturation (m = an integer between 1 and N_S). The primary hue in each pixel of the latent image is designated as belonging to one of S_1-S_{NS}, and the pixel is addressed accordingly, [(p,q)nh,S_m].

6. Each pixel in the primary pattern has a similarly unique address [(p,q)nh,ns] according to its position in the [p x q] matrix, its hue, and its saturation. The primary pattern is now divided into X blocks of pixels (X = an integral number), each of which represents the smallest possible repeating unit in the primary pattern. The addresses of the pixels in each block are modified to indicate their block number, x, as follows [(p,q)nh,NS,x] (x = an integral number between 1 and X)

7. Pixels [(p,q)nh,S_m] in the latent image are now assigned a block number, x, equal to the block number of the pixel having the same values of p and q in the primary pattern, without regard for the respective values of nh and S_m. Pixels in the latent image now have an address [(p,q)nh,S_m,x] in which the value of x corresponds to that of the pixel having the same values of p and q in the primary pattern. Thus, pixels of the latent image have been related to pixels of the primary pattern.

8. Using the latent image, the average saturation S_m^{av} is now calculated for each hue nh for all of the pixels in each block, x. Each block is consequently assigned a descriptor $\{S_{m'}^{1}, S_{m''}^{2}, \ldots S_m^{nh}\}x$ to describe the average saturation, S_m, for each hue nh in each block x. The average saturation can only take one of the available saturation levels. S_m is the value of saturation which is subsequently used to determine how pixels in the primary pattern are displaced.

9. In each corresponding block x in the Primary Pattern, pixels of each hue nh are now displaced along one of the image axes according to the saturation level of the hue (S_m) in the descriptor for that block, $\{S_{m'}^{1}, S_{m''}^{2}, \ldots S_m^{nh}\}x$. This movement may be either along one axis or another, or combinations of movements along both of the axes simultaneously. As in the previous embodiments, a variety of displacements can be employed. In a common embodiment, each pixel is displaced as follows:

by 1 pixel for S_1

.....

by N_S pixels for S_{NS}

or, in general,

by m pixels for S_m

Alternatively, a formula such as the following can be used:

$$D = (N_S-1) \times [(S-S_{min})/(S_{max}-S_{min})]$$

where D = the displacement (i.e. the number of pixels to be moved)

Direct assignment of equally spaced D values to particular saturation levels via a table is also a valid method.

The pairing of the most intense saturation with highest shift can also be reversed i.e. lightest saturation with highest shift will provide a similar result.

The formulae shown above provide a broad contrast range. Other formulae will be appropriate in other applications.

The resulting image is the secondary pattern and is, in effect, a displaced version of the primary pattern, where the displacement is dependent on the relationship established between pixels of the latent image and pixels of the primary image.

In the fourth embodiment, a suitable primary pattern is chosen and then the following steps are undertaken in the manual conversion of the primary pattern to the secondary pattern:

1. The total number of possible saturation levels (N_S) is determined from the composition of the primary pattern.

2. Using standard image processing techniques, an original image is processed and digitised in order to provide the latent image.

3. The latent image is then colour separated into a number of hue images representing each of the primary hues, using standard image processing techniques. Each hue image is a gray-scale picture produced as a colour separation from the original image, wherein the shade of

gray represents a particular saturation of the particular hue.

4. Each hue image is analysed to determine the highest saturation level of each primary hue. These values are subsequently used to define the primary hue saturation levels used later to produce displaced partial primary patterns as discussed in further detail below.

5. Using standard image processing techniques, the dynamic range of each hue image is expanded to the maximum available (the limit may vary depending on the software being used), the dynamic range is then reduced to N_S saturation levels, before the dynamic range is expanded again.

6. Each hue image is now separated into N_S masks, each containing only the pixels belonging to one hue (i.e. belonging to S^*_1-S^*_{NS}) using standard methods in commercially available imaging programs such as Photoshop (available from Adobe Systems Incorporated, www.adobe.com). Each mask contains a unique set of pixels from the image and every pixel can be found in only one of the masks. If all of the masks from one primary hue set are combined at their correct saturation levels, the original hue image is restored.

7. N_H partial primary patterns are created by colour separation of the primary pattern, each of these partial primary patterns only contains a single primary hue.

8. A displaced partial primary pattern is created for each mask corresponding to it's hue and saturation. The saturation levels are designated S^*_1-S^*_{NS}. The displacement may be either right or left, or up or down, or combinations of movements along both of the axes simultaneously. The displacement is defined by a

mathematical operation (algorithm) performed on each individual pixel S^*_1-S^*_{NS}. The displacement is different for each S^*_1-S^*_{NS}. A variety of displacements can be employed. In a common embodiment, each pixel is displaced as follows:

by 1 pixel for S^*_1

.....

by N_S pixels for S^*_{NS}

or, in general,

by m pixels for S^*_m

Alternatively, a formulas such as the following can be used:

$$D = (N_S-1) \times [(S-S^*_{min})/(S^*_{NS}-S^*_{min})]$$

where D = the displacement (i.e. the number of pixels to be moved)

Direct assignment of equally spaced D values to particular saturation levels via a table is also valid method.

The pairing of most intense saturation with highest shift can also be reversed i.e. lightest saturation with highest shift will provide a similar result.

The formulae shown above provide a broad contrast range. Other formulae will be appropriate in other applications.

9. The masks are used to cut-out sections of the corresponding displaced partial primary patterns, thereby

relating pixels of the latent image to pixels of the partial primary patterns. The resulting $N_S \times N_H$ displaced partial primary patterns are each assemblies of portions of the corresponding, shifted primary pattern.

10. The displaced partial primary patterns are now recombined to form the secondary pattern which is a displaced version of the primary pattern where the displacement is based on the saturation levels of the latent image pixels with which a relationship has been established.

Alternative embodiments

Persons skilled in the art will appreciate that a number of variations may be made to the foregoing embodiments of the invention, for example, while the image elements are typically pixels the image elements may be larger than pixels in some embodiments - e.g. each image element might consist of 4 pixels in a 2 x 2 array.

In some embodiments, once the secondary pattern has been formed, a portion (or portions) of the secondary pattern may be exchanged with a corresponding portion (or portions) of the primary pattern to make the latent image more difficult to discern.

Further security enhancements may include using colour inks which are only available to the producers of genuine bank notes, the use of fluorescent inks or embedding the images within patterned grids or shapes.

The method of at least the first and second preferred embodiments may be used to encode two latent images, with one secondary pattern providing the primary pattern for the other secondary pattern and vice versa. This is achieved by forming two secondary images using the

method described above. The images are then combined at an angle which may be 90 degrees (which provides the greatest contract) or some smaller angle. The images are combined by overlaying them at the desired angle and then keeping either the darkest of the overlapping pixels or the lightest of the overlapping pixels, depending on the desired level of contrast.

<u>Application of the preferred embodiments</u>

The method of preferred embodiments of the present invention can be used to produce security devices to thereby increase security in anti-counterfeiting capabilities of items such as tickets, passports, licences, currency, and postal media. Other useful applications may include credit cards, photo identification cards, tickets, negotiable instruments, bank cheques, traveller's cheques, labels for clothing, drugs, alcohol, video tapes or the like, birth certificates, vehicle registration cards, land deed titles and visas.

Typically, the security device will be provided by embedding the secondary pattern within one of the foregoing documents or instruments and separately providing a decoding screen in the form which includes the primary pattern. However, the primary pattern could be carried by one end of a bank note while the secondary pattern is carried by the other end to allow for verification that the note is not counterfeit.

<u>Example</u>

In this example, a secondary pattern is formed using the method of the second preferred embodiment.

Figure 1 is an example of an original image. The

original image was of fairly low resolution (104 by 147 pixels) and was a 256-colour image although it is shown in black and white for the sake of convenience.

The colour image of Figure 1 was then reduced to a gray-scale picture and the shades of gray were then equalised to provide the greatest shade separation. The image was then reduced to four shades of gray using the optimised median cut method with aero diffusion. The result is illustrated in Figure 2.

In terms of the 8 bit RGB colour scale the shades in this picture consisted of [228R/228G/228B], [164/R.164G.164/B], [98/R/98G/98B] and [28R/28G/28B]. Further equalisation was thought to be unnecessary as the full shade range from phase modulation would only be from 50 to 100% black with losses due to the use of transparent media.

This image was separated into masks representing the required shades. (Note that the lightest shade [228R/228G/228B] will serve as a background and therefore does not need a mask).

Figure 3a is the mask for shade 28. Figure 3b is the mask for shade 98. Figure 3c is the mask for shade 164. These masks are positive masks as the black areas define the areas that will be filled with each shade.

A primary pattern of black lines 3 printer pixels wide and spaced apart by 3 printer pixels is to be used. Considering the primary pattern as a reference, the different shades are to be encoded using a phase shift of zero printer pixels for the lightest shade, one printer pixel for the 164 shade, 2 printer pixels for the 98 shade and 3 printer pixels for the 28 shade. This of course will not produce an exact match to the original shades but

this will only affect the contrast and brightness of the final observed image.

The phase shifts are illustrated diagrammatically in Figure 4, where Figure 4a relates to shade 28, Figure 4b relates to shade 98, Figure 4c relates to shade 164, and Figure 4d relates to shade 28. In each case the upper line relates to the primary pattern and the lower line relates to the displaced primary pattern.

A set of four displaced primary patterns were prepared with the required phase difference as illustrated in Figure 4. These are illustrated in Figures 5a to 5d. Where Figure 5a relates to shade 28, Figure 5b relates to shade 98, Figure 5c relates to 164 and Figure 5d relates to shade 228. These partial primary patterns are 18 times the linear size of the original portrait masks. That is, 1872 by 2646. The three masks were also expanded from 104 by 147 pixels to 1872 times 2646 pixels. This expansion was to ensure that sufficient pixels were available to define the shades in the final image. In essence, each pixel in the original latent image was expanded to a super-pixel of 18 by 18 pixels. Therefore it could be defined in shade by a pattern made up of lines composed of normal pixels.

In order to combine the partial primary patterns, the shade 228 image was used as the background and sections of it were replaced by the other shade images as follows:

Firstly the mask of the 164 shade was used to white out the required areas on the shade 228 image as illustrated in Figure 6. Figure 7 shows a detail of Figure 6 corresponding to the boxed area.
Next the mask for the 164 shade is used to mask out the 164 shade line image as shown in Figure 8. Again a detail

of the right eye (as indicated by the box in Figure 8) is shown in Figure 9. The image shown in Figure 8 was added to the image of Figure 6 to produce the image shown in Figure 10. Again a close up of the right eye of Figure 10 is shown in Figure 11.

The process is repeated using the image produced in Figure 10 for the addition of the shade 98 elements using the same procedure as used for shade 164.

This is then repeated with shade 98 to produce the complete latent image shown in Figure 12. Again detail of Figure 12 is shown in Figure 13.

Figures 14 and 15 illustrate how, when the primary pattern is overlayed on the image of Figures 12 and 13, the latent image reappears in a manner which approximates the original latent image.

Fig 1

Fig 2

Fig 3a, 3b, 3c

Fig 4a

Used for shade 28

Fig 4b

Used for shade 98

Fig 4c

Used for shade 164

Fig 4d

Used for shade 228

Shade 28 Fig 5a

Shade 98 Fig 5b

Shade 164 Fig 5c

Shade 228 Fig 5d

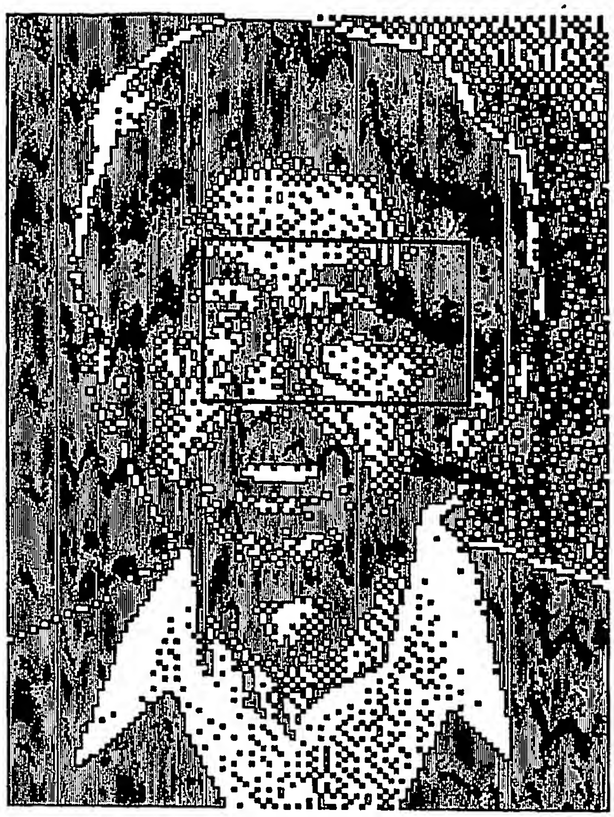

Figure 6

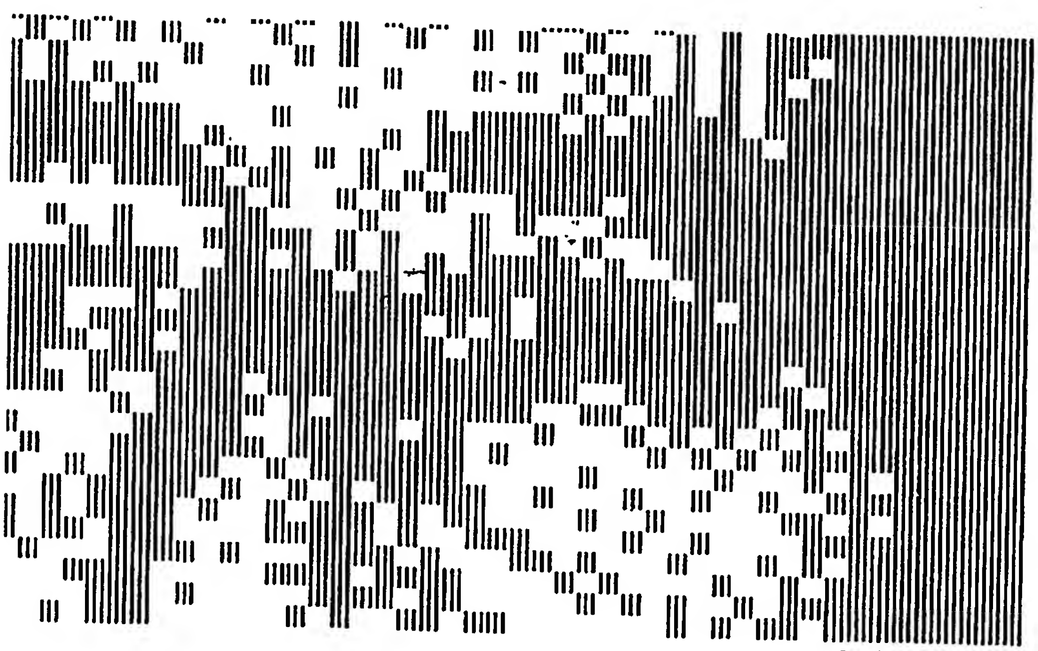

FIG. 7

Figure 8

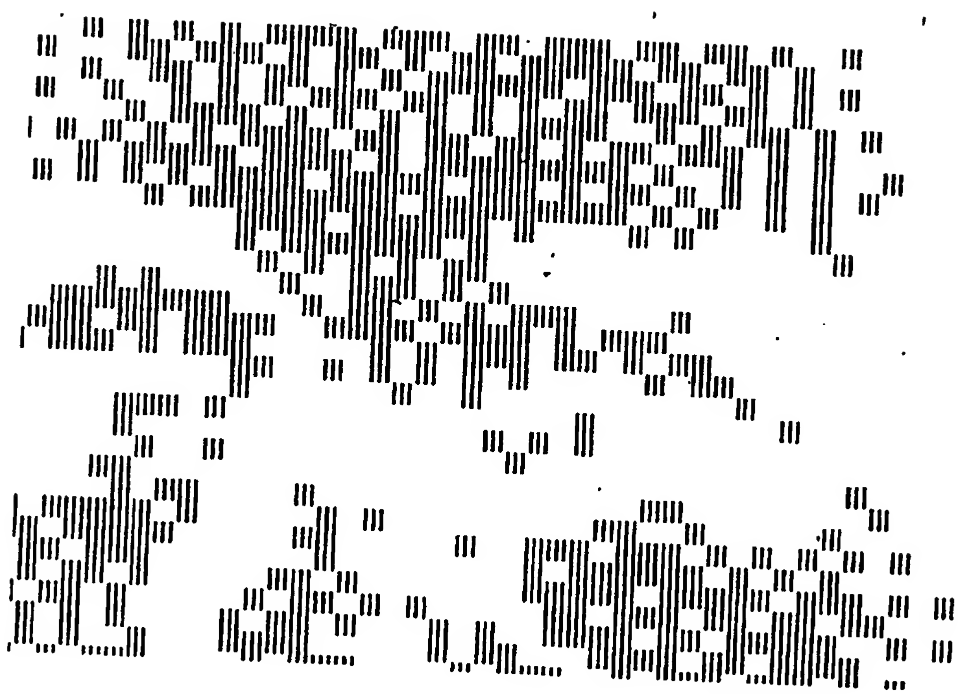

FIG 9

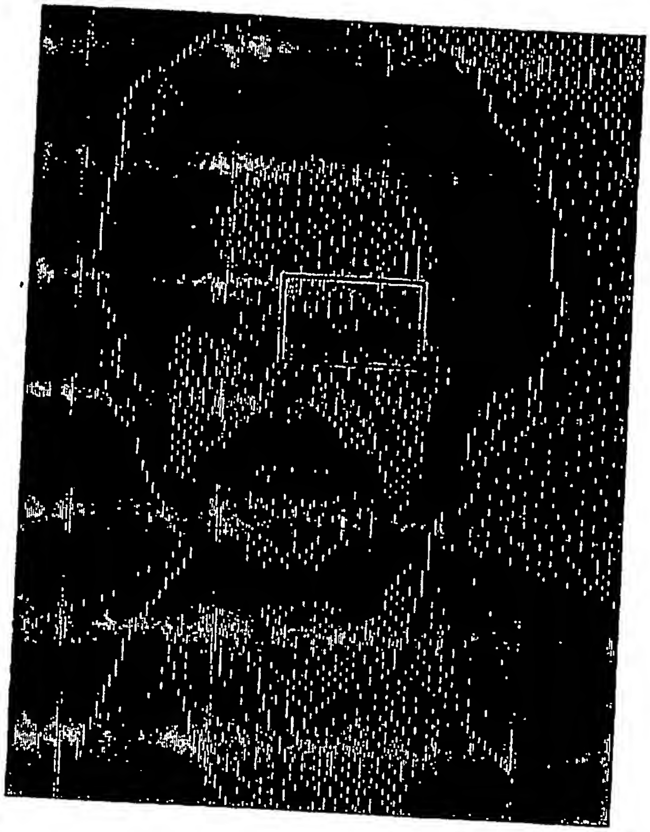

Figure 10

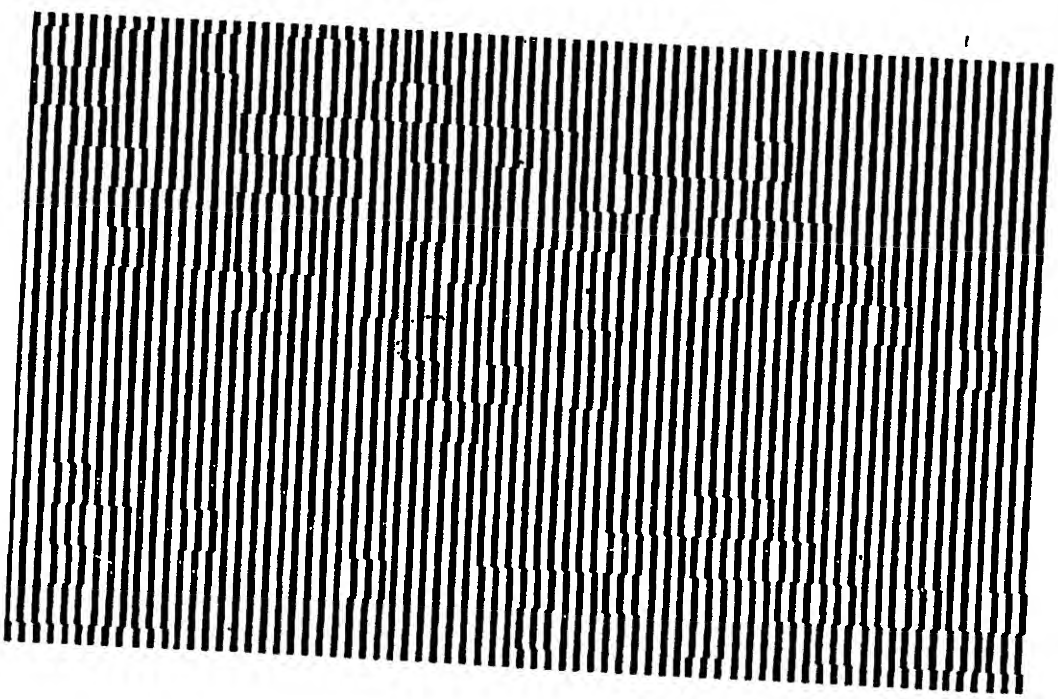

FIG 11

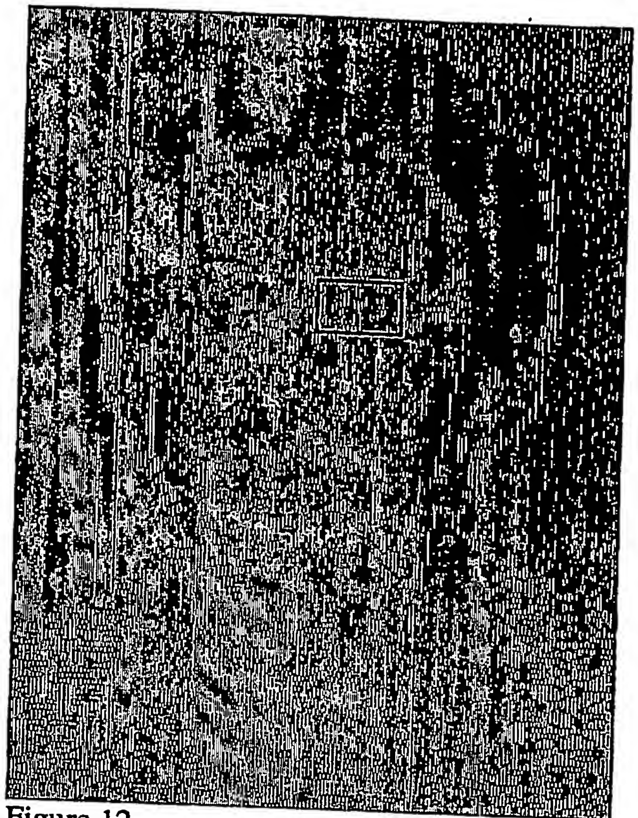

Figure 12

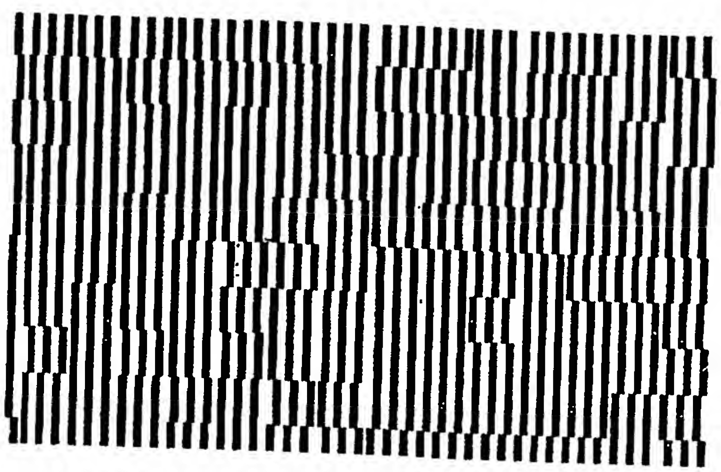

Fig 13

Figure 14

Figure 15